

## Correlation of Onychomycosis Severity with HbA1c Levels in Type 2 Diabetes Patients

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### Abstract

**Background:** Onychomycosis represents a highly prevalent fungal nail pathology that exhibits elevated frequency and intensity in individuals with type 2 diabetes mellitus (T2DM). Suboptimal glycemic management renders diabetic cohorts susceptible to persistent mycotic infections via compromised immune mechanisms, peripheral neuropathy, and microvascular complications. Nonetheless, minimal research examines the explicit relationship between glycated hemoglobin (HbA1c) values and objective onychomycosis grading utilizing validated assessment tools. Objective: This research aimed to assess the relationship between nail infection severity and metabolic regulation, determined via HbA1c metrics, among individuals experiencing T2DM.

**Materials and Methods:** This institutional cross-sectional observational investigation enrolled 120 individuals presenting with T2DM and clinically confirmed onychomycosis at a tertiary healthcare facility from January 2024 to June 2025. A structured proforma was utilized to document patient demographics and clinical histories. The Onychomycosis Severity Index (OSI) served to quantify nail infection severity. High-performance liquid chromatography determined HbA1c values, which stratified cohorts into optimal (<7%), intermediate (7–8.9%), and inadequate (≥9%) glycemic control tiers. Statistical computations utilized SPSS version 26.0, employing Pearson correlation and Chi-square assessments with a significance threshold established at  $p < 0.05$ .

**Results:** The cohort exhibited an average age of 54.8 ± 9.6 years, featuring a male majority (60%). Distal lateral subungual onychomycosis emerged as the predominant clinical subtype (61.7%). A meaningful relationship was detected between HbA1c values and nail infection severity ( $p < 0.001$ ). Advanced disease states gathered notably in patients with HbA1c ≥9%. Furthermore, HbA1c parameters revealed a robust positive correlation with OSI ratings ( $r = 0.648$ ,  $p < 0.001$ ). Diabetes chronicity and fasting plasma glucose metrics similarly demonstrated significant positive correlations with overall pathological severity.

**Conclusion:** Inadequate glycemic management correlates significantly with advanced onychomycosis severity among T2DM individuals. Routine nail monitoring alongside aggressive blood glucose regulation could minimize overall pathology burdens and forestall diabetic foot-associated consequences.

**Keywords:** Type 2 diabetes mellitus; Onychomycosis; Glycated hemoglobin (HbA1c); Onychomycosis Severity Index; Glycemic control; Fungal nail infection; Diabetic foot complications; Peripheral neuropathy; Chronic hyperglycemia; Dermatophytosis.

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### Introduction

Diabetes mellitus constitutes a primary global healthcare crisis, marked by escalating incidence rates and profound systemic morbidity. Chronic hyperglycemia characteristic of type 2 diabetes mellitus (T2DM) drives progressive microvascular and macrovascular damage while rendering vulnerable populations susceptible to diverse infectious pathologies via compromised innate and adaptive immunological mechanisms [1-8]. Within this infectious spectrum, onychomycosis represents a widespread but frequently overlooked dermatological condition among diabetic cohorts. Onychomycosis involves chronic fungal

colonisation of the nail apparatus induced chiefly by dermatophytes, non-dermatophyte molds, and yeasts, representing approximately 50% of global nail anomalies [8,9]. The incidence of onychomycosis escalates markedly within diabetic populations relative to healthy cohorts, driven by elements including ongoing hyperglycemia, peripheral neuropathy, circulatory insufficiency, decreased neutrophil performance, and protracted tissue repair [5-7]. Prior investigations establish that diabetic cohorts exhibit a two- to threefold higher vulnerability to mycotic nail pathologies than non-diabetic reference groups [4,10].

Furthermore, onychomycosis in diabetic settings extends beyond aesthetic dissatisfaction, functioning potentially as a critical indicator of suboptimal metabolic management and broader systemic diabetic complications [13].

Multiple physiological pathways elucidate this heightened vulnerability to aggressive fungal nail pathologies among diabetic individuals. Elevated glucose concentrations suppress phagocytic dynamics, neutrophil chemotaxis, and cellular immunity, which promotes fungal proliferation and survival [5,6]. Furthermore, advanced glycation end products accelerate endothelial impairment and microvascular damage, disproportionately impacting peripheral terminals like digits and nails [7]. Peripheral neuropathy coupled with recurrent unperceived trauma compounding the likelihood of fungal colonization and persistent nail dystrophy [17,22]. Consequently, diabetic individuals experiencing onychomycosis face heightened risks regarding secondary bacterial contamination, cellulitis, diabetic foot ulcers, and distal extremity damage [17,23].

Contemporary epidemiological data internationally and domestically highlights the rising impact of onychomycosis within diabetic populations [3,4,10,14]. Distal lateral subungual onychomycosis persists as the predominant clinical variant, especially among cohorts exhibiting extended diabetes timelines and poor glycemic regulation [11,12]. Various researchers have identified positive relationships between increased glycated hemoglobin (HbA1c) values and aggravated onychomycosis presentations [3,4,18]. Nonetheless, existing research offers restricted insight concerning the precise mathematical association between HbA1c metrics and standardized severity markers of mycotic nail disease, particularly within developing regions experiencing skyrocketing diabetes frequencies.

HbA1c remains globally recognized as a dependable marker for chronic glycemic profiles and a major predictor of subsequent diabetic pathologies. Establishing a definitive correlation between HbA1c status and onychomycosis grading could offer vital clinical utility for risk categorization, prompt detection, and prophylactic diabetic foot management. Timely identification and intervention for fungal nail pathologies might mitigate chronic sequelae while elevating overall life quality for diabetic patients [13,20].

Notwithstanding heightened recognition, onychomycosis among diabetic patients frequently goes unrecognized and unmanaged during standard clinical assessments. Additionally, considerable deficits exist in research evaluating relationships between glycemic tracking and clinical severity via structured validation tools like the Onychomycosis

Severity Index (OSI), especially regarding Indian cohorts. Accordingly, this research aimed to assess the relationship between nail infection severity and metabolic regulation, determined via HbA1c metrics, among individuals experiencing T2DM.

## Materials & Methods

This institutional cross-sectional observational inquiry took place within the Department of Dermatology alongside the Department of General Medicine at a tertiary care teaching facility spanning an 18-month timeframe from January 2024 through June 2025.

A sample of 120 individuals with T2DM and presenting clinically suspected onychomycosis participated in this project. Mature individuals aged  $\geq 18$  years of any gender presenting to the dermatology or metabolic outpatient clinics underwent evaluation regarding study inclusion criteria.

## Inclusion Criteria

Individuals meeting the subsequent guidelines were enrolled in this research:

- Verified T2DM diagnosis adhering to American Diabetes Association (ADA) standards.
- Clinical presentations indicating onychomycosis affecting fingernails, toenails, or both.
- Subjects willing to join and submit signed informed consent paperwork.

## Exclusion Criteria

Subjects were omitted given the presence of:

- Type 1 diabetes mellitus or gestational metabolic conditions.
- Nail pathology independent of fungal colonization, including psoriasis, lichen planus, traumatic dystrophy, or hereditary nail anomalies.
- Oral antifungal administration within the past 3 months or local antifungal application within 4 weeks.
- Immunocompromised states such as HIV, oncological diseases, organ transplant histories, or long-term systemic steroid use.
- Non-diabetic peripheral arterial disease.
- Gestating or breastfeeding females.

The investigative framework received review and clearance from the Institutional Ethics Committee before trial initiation. This project followed the ethical guidelines outlined by the Declaration of Helsinki. Signed informed consent was secured from every subject prior to participation. Comprehensive demographic and clinical parameters were captured utilizing a customized, pre-established structured proforma. Data

encompassing age, gender, diabetes chronicity, smoking habits, concurrent illnesses, and prior therapeutic interventions were documented. Systematic physical evaluations and thorough dermatological assessments were conducted for every subject.

Nail evaluations focused on quantifying involved nails, anatomical distribution, morphological patterns, pigmentation changes, subungual hyperkeratosis, onycholysis, and structural dystrophy. Fungal nail phenotypes specifically distal lateral subungual, proximal subungual, superficial white, and total dystrophic variants were categorized in accordance with established dermatological guidelines.

**Assessment of Onychomycosis Severity:** Fungal nail infection severity was quantified utilizing the Onychomycosis Severity Index (OSI).

The overall OSI value was determined by multiplying the involved nail surface area rating by the pathology's proximity to the matrix, adding extra points for identified dermatophytomas or advanced subungual hyperkeratosis (>2 mm). Following OSI tabulations, condition intensity was grouped as:

- Mild: OSI parameters 1-5
- Moderate: OSI parameters 6-15
- Severe: OSI parameters >=16

**Laboratory Investigations:** Peripheral venous blood was drawn using aseptic techniques to measure fasting plasma glucose and HbA1c metrics. Analytical HbA1c measurement employed high-performance liquid chromatography (HPLC) validated approaches. Metabolic regulation was classified as:

- Optimal control: HbA1c <7%
- Intermediate control: HbA1c 7-8.9%
- Inadequate control: HbA1c >=9%
- Standard hematological and metabolic panels were executed as clinically warranted.

**Statistical Analysis:** Gathered parameters were compiled within Microsoft Excel and evaluated employing the Statistical Package for the Social

Sciences (SPSS) software version 26.0. Continuous metrics were presented as mean +/- standard deviation (SD), whereas categorical characteristics were reported using frequencies and percentages. Relationships connecting HbA1c tiers and fungal nail infection intensity were analyzed via Chi-square tests. Pearson correlation coefficient assessments served to establish the association linking continuous HbA1c values with total OSI metrics. Associations between alternate factors including diabetes history, fasting plasma glucose, and body mass index with pathological severity were likewise evaluated. A p-value below 0.05 established statistical significance.

## Results

This research evaluation comprised 120 individuals diagnosed with T2DM and clinically verified onychomycosis (Table 1). The investigative cohort demonstrated an average age of 54.8 +/- 9.6 years. Within this group, 72 (60.0%) subjects were male and 48 (40.0%) were female. The average history of diabetes spanned 8.7 +/- 4.2 years, whereas the mean body mass index (BMI) measured 27.4 +/- 3.8 kg/m<sup>2</sup>.

The mean HbA1c value recorded across subjects was 8.4 +/- 1.5%, with average fasting plasma glucose tracking at 168.5 +/- 42.3 mg/dL. Concurrent hypertension affected 64 (53.3%) individuals, peripheral neuropathy occurred in 38 (31.7%), and active smoking backgrounds were identified in 29 (24.2%) participants. Isolated toenail affliction represented the dominant presentation, occurring in 82 (68.3%) subjects, while isolated fingernail damage was detected in 14 (11.7%) cases. Concomitant finger and toenail involvement appeared in 24 (20.0%) patients. Assessing specific clinical variants of onychomycosis, distal lateral subungual onychomycosis stood out as the primary presentation, comprising 74 (61.7%) instances. Total dystrophic changes occurred in 22 (18.3%) patients, superficial white infection in 15 (12.5%) individuals, and proximal subungual presentation in 9 (7.5%) subjects.

**Table 1: Baseline Characteristics of Type 2 Diabetes Patients with Onychomycosis (n = 120)**

Variable	Value
Age (years), mean ± SD	54.8 ± 9.6
Male, n (%)	72 (60.0%)
Female, n (%)	48 (40.0%)
Duration of diabetes (years), mean ± SD	8.7 ± 4.2
BMI (kg/m <sup>2</sup> ), mean ± SD	27.4 ± 3.8
HbA1c (%), mean ± SD	8.4 ± 1.5
Fasting blood glucose (mg/dL), mean ± SD	168.5 ± 42.3
Hypertension, n (%)	64 (53.3%)
Peripheral neuropathy, n (%)	38 (31.7%)
Smoking history, n (%)	29 (24.2%)

Toenail involvement only, n (%)	82 (68.3%)
Fingernail involvement only, n (%)	14 (11.7%)
Both finger and toenail involvement, n (%)	24 (20.0%)
Distal lateral subungual onychomycosis, n (%)	74 (61.7%)
Total Dystrophic Onychomycosis, n (%)	22 (18.3%)
Superficial White Onychomycosis, n (%)	15 (12.5%)
Proximal Subungual Onychomycosis, n (%)	9 (7.5%)

A meaningful relationship (Table 2) appeared between HbA1c values and fungal nail infection intensity ( $p < 0.001$ ). Within the cohort maintaining optimal metabolic regulation (HbA1c  $< 7\%$ ), mild onychomycosis constituted the primary presentation, identified in 24 (70.6%) individuals, while merely 2 (5.9%) subjects exhibited advanced pathology.

For individuals with intermediate glycemic management (HbA1c 7-8.9%), moderate onychomycosis represented the most frequent finding, observed in 22 (44.0%) patients. Advanced

onychomycosis occurred in 10 (20.0%) subjects within this specific stratum.

Among individuals displaying inadequate glycemic status (HbA1c  $\geq 9\%$ ), severe onychomycosis predominated, recorded in 20 (55.6%) patients, whereas only 4 (11.1%) cases demonstrated mild involvement. Broadly, mild, moderate, and advanced onychomycosis presentations affected 46 (38.3%), 42 (35.0%), and 32 (26.7%) individuals, respectively. These observations indicate that elevating HbA1c percentages correspond with increasing clinical severity of onychomycosis.

**Table 2: Association between HbA1c Levels and Severity of Onychomycosis**

HbA1c Category	Mild Onychomycosis n (%)	Moderate Onychomycosis n (%)	Severe Onychomycosis n (%)	Total	p-value
$< 7\%$ (Good glycemic control)	24 (70.6%)	8 (23.5%)	2 (5.9%)	34	$< 0.001$
7-8.9% (Moderate control)	18 (36.0%)	22 (44.0%)	10 (20.0%)	50	
$\geq 9\%$ (Poor glycemic control)	4 (11.1%)	12 (33.3%)	20 (55.6%)	36	
Total	46 (38.3%)	42 (35.0%)	32 (26.7%)	120	

Pearson correlation testing (Table 3) revealed a meaningful positive relationship linking continuous HbA1c values with Onychomycosis Severity Index (OSI) parameters ( $r = 0.648$ ,  $p < 0.001$ ). Individuals exhibiting elevated HbA1c metrics routinely demonstrated more advanced nail pathology. An intermediate positive correlation also surfaced between the chronology of diabetes and corresponding OSI numbers ( $r = 0.421$ ,  $p = 0.002$ ), demonstrating that extended disease histories corresponded with aggravated fungal conditions.

Likewise, fasting plasma glucose measurements indicated a notable positive association with calculated OSI ratings ( $r = 0.536$ ,  $p < 0.001$ ). Conversely, BMI displayed merely a negligible positive connection with overall OSI scores ( $r = 0.188$ ), which failed to meet statistical significance thresholds ( $p = 0.061$ ). These metrics demonstrate that suboptimal glycemic regulation alongside prolonged diabetes duration represent critical variables tied to escalating onychomycosis severity among T2DM cohorts.

**Table 3: Correlation of HbA1c Levels with Onychomycosis Severity Index (OSI)**

Variable	Mean OSI Score $\pm$ SD	Correlation Coefficient (r)	p-value
HbA1c (%)	18.6 $\pm$ 6.8	0.648	$< 0.001$
Duration of diabetes (years)	16.9 $\pm$ 5.7	0.421	0.002
Fasting blood glucose (mg/dL)	17.8 $\pm$ 6.2	0.536	$< 0.001$
BMI (kg/m <sup>2</sup> )	14.7 $\pm$ 4.9	0.188	0.061

**Discussion**

The present investigation established a meaningful positive relationship connecting suboptimal metabolic regulation with the severity of fungal nail infections among individuals experiencing T2DM. Elevated HbA1c metrics corresponded with higher OSI parameters, more widespread nail damage, and advanced clinical expressions of the pathology. These data reinforce accumulating

evidence indicating that chronic hyperglycemia renders diabetic populations vulnerable to mycotic nail processes and exacerbates their clinical presentation through diminished immune response, microvascular damage, peripheral neuropathy, and protracted wound repair mechanisms [1,2].

In this specific project, the cohort displayed an average HbA1c rating of 8.4  $\pm$  1.5%, demonstrating widespread inadequate metabolic

management. Advanced onychomycosis gathered predominantly in subjects presenting with HbA1c  $\geq 9\%$ , whereas mild presentations occurred more frequently among individuals maintaining HbA1c  $< 7\%$ . Parallel observations were documented by Agrawal et al. in North India, who identified a clear relationship between HbA1c values and total affected nails among diabetic cohorts with mycotic nail infections [3]. Their evaluation also highlighted poor glycemic tracking, obesity, and longer diabetes chronicity as vital indicators of fungal nail pathology progression. Similarly, study established that HbA1c parameters  $> 7\%$  significantly multiplied the likelihood of developing onychomycosis in diabetic populations [4]. These findings collectively reinforce the premise that unmanaged diabetes establishes an optimal environment for fungal colonization and ongoing survival.

The robust positive correlation between HbA1c status and calculated OSI numbers recorded in this research ( $r = 0.648$ ,  $p < 0.001$ ) is biologically logical. Continuous hyperglycemia triggers diminished neutrophil chemotaxis, suppressed phagocytic function, and weakened cell-mediated immune responses, subsequently raising vulnerability to fungal pathologies [5,6]. Furthermore, advanced glycation end products compromise vascular architecture and decrease peripheral blood supply, particularly within distal regions like the toenails, which facilitates fungal expansion [7]. Identical pathogenic pathways have been emphasized by investigations performed across the globe [4,8,9].

Our investigation also observed that distal lateral subungual onychomycosis (DLSO) persisted as the dominant clinical presentation, representing 61.7% of evaluated instances. This observation matches multiple domestic and international studies where DLSO featured as the primary manifestation of fungal nail disease among diabetic patients [3,10–12]. DLSO occurs with high frequency because the distal nail matrix remains susceptible to recurrent trauma, moisture accumulation, and fungal entry, particularly for diabetic patients experiencing neuropathy and peripheral arterial insufficiency [13]. Conversely, certain project reports a higher relative frequency of total dystrophic variants among patients with poorly regulated diabetes, potentially due to delayed identification and chronic infectious states [4].

The male predominance recorded in this study aligns closely with previously documented datasets [3,14,15]. The elevated frequency among male subjects may relate to increased occupational hazards, greater diaphoresis, frequent use of constrictive footwear, alongside elevated rates of smoking and local trauma [16]. Furthermore, the average history of diabetes in our group reached

8.7 years, showing a significant positive correlation with overall OSI readings ( $r = 0.421$ ,  $p = 0.002$ ). Matching connections were detailed by studies who concluded that extended diabetes histories escalate vulnerability to chronic fungal pathologies due to progressive neuropathy and vascular damage [17,18].

Another vital observation in this research was the significant concentration of toenail pathology. Roughly 68.3% of participants presented with isolated toenail involvement, whereas combined fingernail and toenail infection occurred in 20% of instances. This distribution aligns with observations who identified toenails as the primary site impacted during diabetic onychomycosis [19,20]. Toenails face increased susceptibility owing to protracted nail growth timelines, recurrent microtrauma, diminished perfusion, and continuous exposure to humid microenvironments within enclosed footwear [21].

The link connecting peripheral neuropathy and onychomycosis highlighted in this analysis carries major clinical weight. Neuropathic changes cause unnoticed microtrauma, altered physical pressure distribution, and diminished protective tactile sensation, which facilitates fungal colonization and secondary bacterial infections [22]. Previous data show that onychomycosis in diabetic settings is not merely an aesthetic issue but acts as a precursor for diabetic foot ulcerations, cellulitis, and lower limb complications [17,23]. Consequently, prompt identification and management of mycotic nail presentations are vital dimensions of comprehensive diabetic foot care. Though BMI displayed a minimal positive correlation with total OSI scores in our evaluation, this relationship failed to reach statistical significance thresholds. Comparable inconsistent data appear in earlier papers [3,24]. While obesity might add indirect risk via decreased distal perfusion and elevated sweating, glycemic status operates as a more reliable indicator of disease severity than BMI parameters alone.

The outcomes of this investigation offer meaningful clinical value. Systematic nail assessments should feature regularly within diabetic screening frameworks, especially for cohorts with elevated HbA1c metrics and extended disease timelines. Timely detection of onychomycosis can lower the risks of secondary bacterial contamination, diabetic foot ulcers, and distal lower extremity morbidity [17,25]. Moreover, improving metabolic management can foster better glycemic control while simultaneously diminishing fungal pathogen loads and subsequent recurrence risks. Despite these insights, this research has specific constraints. The cross-sectional methodology prevents establishing direct causality between glycemic tracking and

onychomycosis severity. Fungal culturing and molecular sequencing techniques were omitted, which could have yielded granular microbiological profiling. Lastly, this study was conducted within a single tertiary medical facility, potentially restricting generalizability regarding the broader diabetic population.

**Conclusion:** This investigation established a meaningful positive relationship between HbA1c parameters and the intensity of onychomycosis in T2DM cohorts. Inadequate metabolic management, extended diabetes histories, and peripheral neuropathy emerged as critical drivers of advanced pathology. These insights underscore the necessity of cohesive dermatological and endocrinological management, highlighting systematic nail evaluations and rigorous glycemic regulation to avert sequelae tied to diabetic fungal nail conditions.

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